ARCTIC AIRSTRIPS CALL FOR SPECIAL HANDLING

by

Stephen D. TEETOR and Stanley ROSANOFF

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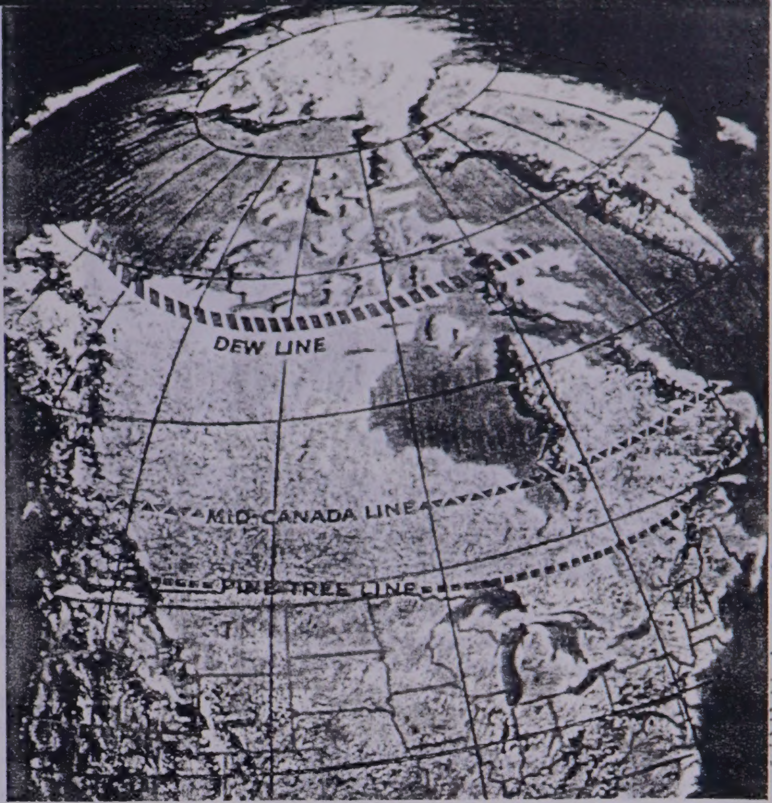

Three radar picket lines now guard polar air approaches to the American continent.

STEPHEN D. TEETOR
and
STANLEY ROSANOFF
Seelye Stevenson Value & Kencht

Stephen D. Teetor received his B.C.E. degree from Cornell University in 1943 and had a wartime tour of duty in the U.S. Navy before joining Seelye Stevenson Value & Knecht in 1946 as a structural designer. In 1951, he was promoted to Supervising Engineer, with responsibility for investigations and major foundations, including detailed inspection work with contractors on foundation installations. Teetor was named an Associate of the firm in 1953, with responsibility for foundation investigations of all types. He became a Partner in 1955.

Stanley Rosanoff studied engineering at CCNY and The Cooper Union. Prior to joining Seelye Stevenson Value & Knecht in 1951, he did civil engineering for a New Jersey Municipal Engineer. In the design of twelve subarctic Pine Tree bases and many DEW line installations, Rosanoff used his wide experience in airfields, water supply, sanitation, drainage, and site selection in the field and in the office. As an associate member of ASCE, he serves on its Committee on Adverse Weather Conditions, Subcommittee on Cold Weather Construction.

A VITAL LINK in this nation's security chain was put into operation in July 1957. The DEW or Distant Early Warning line filled a gap through which a sneak enemy bomber attack was possible.

The arctic segment of the DEW line covers 3000 miles along the 69th parallel from Baffin Bay in eastern Canada westerly across the top of the North American continent to the northwest tip of Alaska.

On the continent the DEW line is backed up by the 2700-mile long Mid-Canada line and along the United States-Canadian border by the Pine Tree line. These three lines are capable of providing information relative to distance, direction, height, and speed of any aircraft detected.

The DEW line, built by Western Electric Company for the USAF and now maintained and operated by Federal Electric, consists of a series of

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electronically interlocked radar stations designed to give us in the continental United States 4 to 6 hours' warning of impending enemy attack, which notice is so necessary to our survival as a nation.

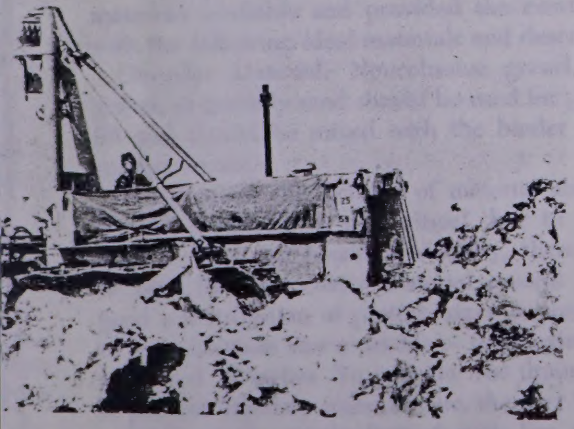
The services of a number of consulting engineers were used on this project, and our firm, Seelye Stevenson Value & Knecht, was employed to assist and advise on the construction of the airstrips and related facilities of the DEW line. In doing reconnaissance, members of this group worked under extremely adverse conditions, typified by a 25,000-mile trip, at temperatures ranging in the minus 30's, with an hour or two of twilight per day. That trip was made in five weeks in arctic bush planes – in the unfavorable weather of early winter.

Arctic Weather

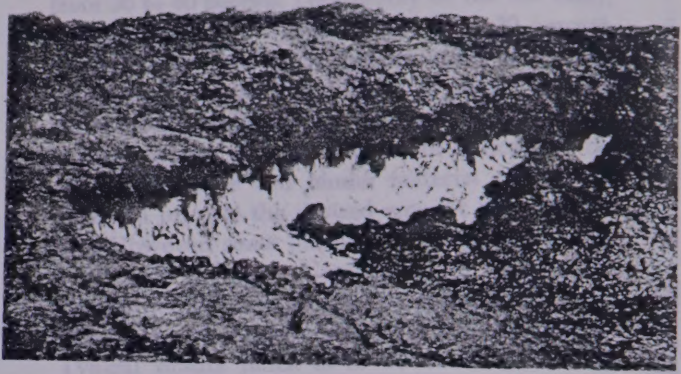
Weather is more than a topic of conversation in the arctic, and an understanding of climatic conditions in the far north is necessary to appreciate arctic engineering and construction.

Initially, men were flown into the project areas in the spring of the year in small bush aircraft, which landed on the ice or snow at each prospective site. Small tractors, parachute dropped or flown in, then were used to prepare airstrips to accommodate larger aircraft, which delivered equipment of greater capacity. The aircraft accommodations grew progressively larger with the size and amount of equipment supplied until most of these strips, carved out of ice and snow, were able to take C-46s and C-47s, thus permitting the easy transportation of men and heavy materials.

In summer, with the melting of the snow and ice strips, permanent airstrips and roads became a necessity. It was for the building of these permanent facilities that our firm's engineering teams were sent into the field to locate accessible sources of construction materials. The idea was to make the maximum use of local materials and to establish standards for the minimum acceptable airstrips. On the return of these men, material specifications and designs were prepared.



Snow removal to keep roads open can be an almost continuous operation during winter months in the arctic.



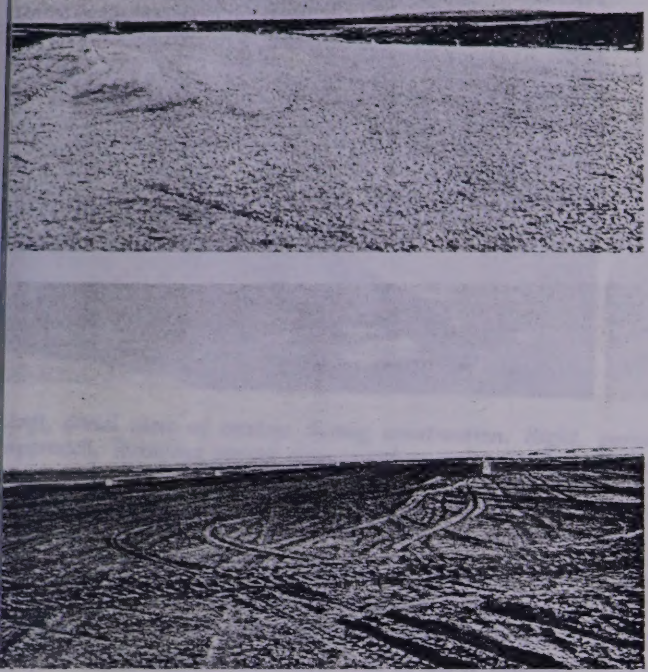
Permafrost is a subsurface permanently frozen layer. This photograph shows a permafrost strata revealed after the side of the knoll had been bulldozed away.

The building of airstrips in permafrost regions involves construction methods and theoretical considerations substantially different from similar projects in more temperate zones. If the permafrost remains frozen, these special problems are minimized; if the permafrost melts as a result of natural or artificial causes, then very serious problems arise.

Permafrost is found at varying depths below the ground surface. In this underground region, below freezing temperatures have existed for thousands of years. The top few feet of permafrost, called the active zone, freeze and thaw seasonally, but below this there is normally only permanently frozen material. Where nonfreezing materials such as gravel are encountered, the active zone is seldom more than five feet in depth. Where tundra and peat moss are found, these materials insulate the earth, decreasing the maximum depth of thaw to about two feet.

Construction experience and field observations indicate that free draining gravel or sand should be used for the basic airstrip fill, but this material, if clean, unfrozen, and not of a uniform gradation, will not have sufficient cohesion to sustain the loads imposed upon an airstrip. A surface course of a more cohesive nature must be provided.

In order to provide good density and frictional stability in the surface course, both fine and coarse



Gravel scraping operation at DEW line site with the completed runway below. Note water to left of runway.

material should be present, with a good distribution of particle sizes. The fine binder material should be predominantly silt or clayey silt.

Specifications

When preparing our specifications, we studied all materials available and provided the contractor with the following ideal materials and descriptions.

Granular Material: Noncohesive gravel, sandy gravel, or gravelly sand should be used for pervious fill and should be mixed with the binder for the surface course.

For pervious fill, grading of material above the No. 40 sieve size is not critical, but to provide good density and frictional stability, there should be both fine and coarse material present with as good a distribution of particle sizes as possible up to the maximum size available – the maximum not to exceed 2½ inches. To provide free drainage and to prevent capillary moisture rise, the very fine material must be strictly limited with less than 2.5 percent passing the No. 200 sieve.

For surface courses, to provide good density and frictional stability, there should be both fine and coarse material present, with as good a distribution of particle size as possible up to the maximum size available – not to exceed 2 inches. In general, the minus No. 4 fraction should range from 30 to 60 percent (preferably on the low side), the minus No. 40 fraction from 10 to 30 percent.

Binder Material: The binder material is composed of both clay and silt which pass a No. 200 sieve. Coarse materials may or may not be included in this mixture. The grading is not critical, for the combined coarse and binder material can be balanced to provide the desired amount of minus No. 200. However, some plasticity is desirable in order to provide cohesion. Good material, when moist, can be rolled out between the palms of the hand into a cohesive thread about 1/16 inch in diameter. Typical tundra muck is to be avoided, but if it must be used, both the live growth and the spongy root mat overlying the muck must be stripped off and discarded. Even when this is done, tundra muck is not a good binder.

Materials Actually Available

Field investigation of the soils at 16 individual airstrips above the Alaskan Brooks Range showed that there was no stone or gravel of size greater than 2½ inches available within practical hauling distance of any of the strips. Therefore, all strips were constructed of local granular material 2½ inches or less in diameter. In all previous fills the granular material was silt-free or contained so little fines as to be adequately pervious. The surface course at three strips was natural pit run silty, sandy gravel; all other surface courses were made up of artifical mixtures of sandy gravel and binder (silt, clayey silt, or tundra muck) or made use of well graded material containing only a little binder.

At some strips at the easterly end of the line none of this material was available, so at these sites it was necessary to blast off chunks of mountains to be run through the rock crushers to produce material of the desired sizes. At these sites it was possible to adhere quite closely to the theoretically desirable size and type of material.

Construction Methods

In building gravel surface airstrips, preservation of the tundra overlying permafrost is mandatory. Unfortunately, this basic rule frequently is violated in the interests of construction expediency. It must be remembered that the ability of the tundra layer to act as an insulator under a superimposed runway fill has proven a most effective way to maintain the integrity of the permafrost layer, which acts as a good foundation for the airstrip itself. This is equally true where peat moss and muskeg exist.

Haulage vehicles should not be allowed to pass over tundra ahead of fill in traveling to and from

Left, aerial view of airstrip during construction. Right, permanent runway as seen from plane making landing pproach. Runways permit year-round operation of heavily loaded C46 and C47 planes supplying the arctic bases.

he source of supply. They must back dump at the orward end of the fill material, and the fill material hen must be bulldozed onto the undisturbed tundra until a minimum cover (2 feet of fill if tundra s frozen, 3 feet if tundra is thawed) of free draining material has been placed. Even then, extensive peration should not be permitted over thawed undra with only 3 feet of fill in place.

Surface Course Placement

Placing of the surface course is equally as impor- ant. Assume a good sandy gravel and a good clayey silt are both available, assume that an 80:20 percent combination is optimum, and assume that naterials are spread on the strip in these proporions. It is obvious that proper average proporions will mean nothing if there is improper mixing nd there remain some pockets of sand-gravel nd some pockets of silt-clay. Lack of proper mixng can nullify all previous steps, and the whole roject may fail through want of expenditure of a mall percentage of time for proper mixing.

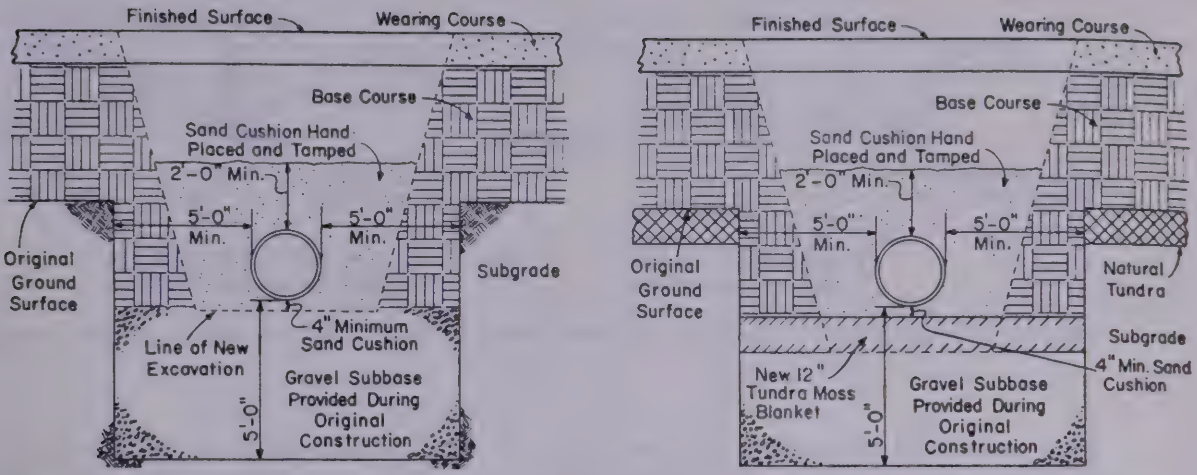
It is obviously impossible to achieve perfect disribution of materials throughout the mass, but he nearer the approach to perfect homogeneity, he better the end result. Therefore, mechanical nixing units that will bite to a minimum depth of inches should be put into operation as soon as ossible. Disc harrows also should be used.

As this equipment is not always available, a ubstitute spike-tooth harrow can be fabricated in the field. A satisfactory harrow can be made of three or more wood beams (minimum 6 x 6 inches), or steel beams of convenient length (say 8 to 10 feet) spaced as desired, having rigid spikes protruding ½ inch to 1 inch below the average depth of the loose layer being worked. Spikes should be regularly spaced 10 to 12 inches apart and staggered evenly from beam to beam. As it is desirable to combine the use of spikes and discs, these should be made even though disc harrows are available.

Distribution of the Binder

One of the difficulties of in-place mixing on the runway is securing adequate distribution of the wet, cohesive, lumpy binder material. The tendency is to skimp on mixing when the material is in the final position. Therefore, where cohesive binder is to be added, it is recommended that the materials be premixed thoroughly prior to placing.

This is not too difficult a job. On the processing area, distribute the materials to be mixed, in the desired proportions, and as uniformly as possible. The total thickness of the loose materials as spread is not critical but should not be too great – 12 to 18 inches is a fair estimate. Roll the material with a dozer blade sharply angled and follow the dozer with a disc or spike harrow or both. Continue turning the materials over, following each dozer pass with a harrow pass, and disperse obviously segregated masses of material until a uni-



Culverts require careful design. These are typical sections of culverts for nontundra (left) and tundra areas.

form, intimate, crumbly mixture, free of large lumps of binder, is secured.

After this, spread the mixture to the desired depth (a 3 to 4-inch loose layer is satisfactory for a pneumatic roller) on the strip and compact. Continue spreading and rolling until the desired total compacted thickness (12 inches optimum) is secured. This will provide a good surface course.

Drainage of Airstrips

Few weather observations have been made in the northern areas, and little is known of the amount of precipitation. It is, however, known that there is a low rate of rainfall. Despite this, drainage is a critical item because of the running water's melting effect on the permafrost. The size and extent of drainage required may vary considerably from that of runway projects in a more temperate zone.

The Civil Aeronautics Administration allows a transverse slope of 3 percent on nonpaved runways. With this slope less water will be able to percolate into the strip than is possible if the designer conforms to lesser transverse slopes of other criteria. This results in less softening of the airstrip surface in time of thaw and increases the period that this strip is available for aircraft operation.

If at all possible, drainage structures are to be avoided. But the accumulation of water adjacent to airstrips and taxiways must be prevented, and so drainage is sometimes essential. When this is true, grading is the first solution to be considered. Grading should limit the runoff water retained and divert the flow away from the installation. Cut should not be permitted without special precautions being taken.

Dikes also can be used to divert the flow of water. These are only practicable in areas of favorable topography and where construction materials such as gravel and silt or clay are readily available.

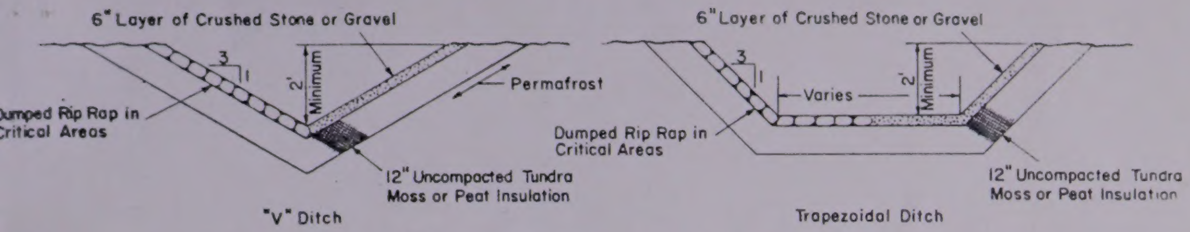
Ditches

Where dikes are not practical, ditches must be used, but degradation of the tundra should be held to a minimum. References are not always clear on this subject. The Navy manual on arctic engineering, for example, suggests that "Deep, narrow channels with relatively small exposure to the atmosphere will be less susceptible to slumping, and their depth will allow free flow of water for a longer period in the late fall than will shallow ones." While this is true, the use of such ditches is feasible only in gravel areas where excessive erosion will not occur, for as S. W. Mueller in his book *Permafrost* suggests, "Wide and shallow drainage ditches are as a rule less susceptible to erosion and slumping." Where deep, narrow ditches are used in nongravel areas, erosion and slumping must be checked by lining the sides and bottom with tundra moss or similar materials. Where these wide, shallow ditches are used and where preservation of the permafrost is a consideration, the ditches should be constructed at the minimum possible grade.

Locating ditches too close to fills on a side hill slope will tend to seriously unstabilize the fill.

Snow Removal

One additional condition is worthy of mention, and that is the effect of snow piled on the shoulders of road and airstrips by snow removal equipment. Keeping the drainage ditches full of snow tends to retard thawing in the early spring. The clear airstrip, however, thaws more readily, but the entrapped water cannot run off. This water tends to boil up through small crevices, and under the



Rip Rap May Be Field Stones. Where Stones Are Not Available Use Burlap Bags Filled With Gravel.

Tundra Moss Insulation May Be Installed Using Burlap Bags.

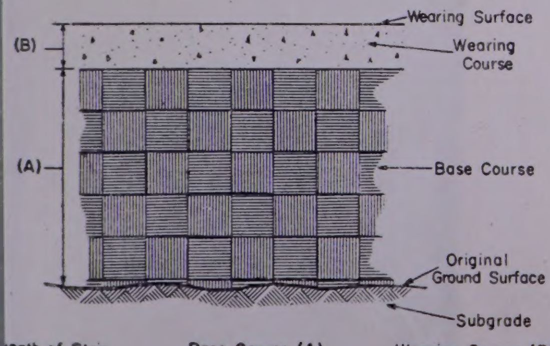
Two types of drainage ditches successfully used in tundra areas. These designs minimize tundra degradation.

ounding action of surface traffic soon develops nto almost impassable quagmire.

It will be appreciated that this condition may ccur frequently, and the best prevention is to take small dozer with its blade angled to cut a V-litch along the approximate ditch centerline and ut it in service prior to the thaw. Starting at the lownstream end of the trench, the dozer can pro-ide a water course which will be enlarged rapidly y the flow of melt water.

Jse of Lampblack

nother method used by the mines around Nome s the spreading of lampblack along the centerline f ditches. Because of a difference in thermo-quali-ies, the lampblack will absorb heat and melt a mall amount of snow in its immediate area. Long ours of daylight tend to speed up this process ntil a small channel is formed. Flowing melt water oes the rest. Other materials possessing differen-ial heat qualities may be used, but the beauty of he lampblack lies in its light weight, which al-ows it to float in the small pool of water it has ormed, thereby continuing its effectiveness.



ngth of Strip	Base Course (A)	Wearing Course (B)
1000'	3'	6"
3500'	4'	12"
5000'	5'	24"

linimum thickness of runway depends mainly on ize of aircraft using it, a function of runway length.

The use of culverts in permafrost is not recommended except where absolutely necessary. Since flowing water will be above freezing temperature, the permafrost may be melted and the result will be uneven settlement with its adverse effect on the surface above. Furthermore, water will tend to flow to the culverts even when they are blocked by snow and ice. This runoff water will accumulate and may result in soft spots on the runway.

Special Approach to Culverts

Where the use of culverts cannot be avoided, special construction methods are required. Excavate the permafrost and backfill with nonfrost-susceptible materials (sand or gravel) to the invert subgrade for a minimum of five feet to each side and below the invert of the culvert pipe. Prior to backfilling, line the cut with an insulating material. Tundra or peat moss taken from some area remote from the site can be used.

Culverts should be provided with headwalls to prevent the washing out of materials under the end of the pipe, and doors should be placed on the culvert ends to keep them free of water when the freeze-up occurs in the fall and to prevent windstorms from blocking culverts with snow. To prevent downstream erosion, flow velocities should be limited. A 0.5-percent slope is recommended.

Grading, ditches, dikes, and culverts are not the answer to every drainage problem in the far north. Each site should be subjected to a detailed study prior to the presentation of any recommendations. Upsetting the hydrological regime can have far-reaching consequences. Some of these will not be immediately apparent and yet actually may result in making the installation completely unusable. For example, any measure permitting subsurface drainage in a permafrost region composed mainly of ice lenses and fine material will cause this ground to become plastic under thawed conditions. This, in turn, would cause roads and airstrips to slump to the level of the existing ground and endanger any existing structures. ▲▲

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